THRESHOLDS EFFECTS, PUBLIC CAPITAL AND THE GROWTH OF THE UNITED STATES*

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ABSTRACT

This paper analyzes the possibility of threshold effects in growth associated with the intensity of public capital. A Solow growth model augmented by human capital is estimated using US states data for the period 1969-86. The existence of a unique regime for all the states is strongly rejected by the data when public capital per capita is used to discriminate shifts in the production function. The rate of convergence for states differs depending on their initial level of public capital. The economic policy implications of these results are discussed.

RESUMEN

El documento analiza la posibilidad de efectos umbral en el crecimiento asociados con la intensidad de capital público. Se estima un modelo de crecimiento de Solow aumentado con capital humano usando datos de los estados estadounidenses para el período 1969-86, rechazándose la existencia de un régimen único para todos los estados, cuando el capital público es utilizado para discriminar movimientos en la función de producción. La tasa de convergencia para los estados difiere dependiendo de su nivel inicial de capital público. Se discuten las implicaciones de la política económica de estos resultados.

1. INTRODUCTION.

Do countries with a low level of per capita income grow faster than rich countries? Several recent studies have analyzed this issue. Although the neoclassical theory predicts convergence, the empirical evidence is subject to considerable controversy.

In a separate line of research, some economists have tried to address the question of whether public infrastructure significantly affects the economic performance of firms and how much the decline in productivity observed at the beginning of the seventies is due to a slowdown in the growth of public infrastructure.

In this paper, we combine the above two lines of research. We analyze the effect of public infrastructure on the convergence hypothesis, in particular whether poor countries or regions converge to the same steady state of developed countries or regions. For this purpose we use US data. The benefit of using regional and state-level data has been recently stressed by Barro and Sala-i-Martin (1991), in their analysis of the convergence of income per capita, and Blanchard and Katz (1991), in their study on the evolution of employment and production in the U.S.

We use a growth model to address the question of how the level of public capital per capita affects the final steady state of output per capita. Although the treatment of public capital in this paper is different from the usual strategy in the public infrastructure literature, the objective is the same: to evaluate the impact of public capital on economic performance. The purpose of this paper is threefold. First, we address the appropriateness of the approach considered by Mankiw, Romer and Weil (1992) in explaining the process of convergence of the U.S. Second, we take seriously into account the possibility of having multiple regimes in the data. Third, we analyze the consequences of having two regimes on the speed of convergence and other important parameters of the model.

The structure of the paper is as follows: Section 2 briefly addresses some of the empirical results discussed in the recent literature on convergence and growth. In the same section we also sketch well known results concerning the impact of public infrastructure on economic performance. Section 3 outlines a theoretical model with a preliminary application to US states data. In section 4, we refine the model discussed in the previous section allowing for the possibility of two regimes. Section 5 concludes.

2. AN OVERVIEW OF THE RELEVANT LITERATURE.

2.1. Growth empirics.

The empirical analysis of the evolution of productivity and output per capita across countries and regions has attracted considerable attention in recent years. Most of these articles have investigated the hypothesis of the convergence of output per capita implied by theoretical growth models based on a production function characterized by decreasing returns to scale. Baumol (1986) reports a clear convergence of productivity across the industrialized economies[1]. The econometric specification used by Baumol is what became later known as the "unconditional convergence regression".

$$\ln y_{i,t} - \ln y_{i,0} = \alpha + \beta \ln y_{i,0} + \epsilon_i$$

Baumol also points out that less developed countries do not follow the same pattern of convergency. De Long (1988) criticized some of Baumol's findings stressing the possibility of sample selection bias in the convergence result given the fact that Baumol only considers developed countries. De Long, including the less developed countries in his sample, finds no evidence of convergence in output per capita. Barro (1991) reaches the same conclusion when developed and developing countries are pooled together[2]. The correlation between the growth rate of per capita GDP and initial GDP is close to zero. However, Barro also notices that when some variables[3] are used to control for differences in steady states, the estimate of the initial level of GDP per capita is negative and significantly different from zero. The specification used is

$$\ln y_{i,t} - \ln y_{i,0} = \alpha + \beta \ln y_{i,0} + \gamma X_i + \epsilon_i$$

where the matrix X_i contains explanatory variables other than the initial level of output per capita.

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[1] Dowrich and Nguyen (1989) report the same result for the OECD countries.

[2] Barro uses 98 countries included in Summers and Heston's database.

[3] Primary and secondary enrollment rates in 1960, average ratio of government expenditure to GNP from 1970 to 1980 and proxies for political stability.

Barro and Sala-i-Martin (1991) provide additional support for the hypothesis of the convergence of output per capita in their study of the US and the regions of Europe. In their estimations the so called "unconditional convergence specification" shows convergence, in contrast to what happens with the countries in the Summer-Heston database. However the size of the coefficient ß is very sensitive to the period of estimation. For this reason the authors include explanatory variables to control for differences in structural composition and agricultural share. The interesting fact emerging from the above studies is that convergence occurs, in all the cases[4], at a rate of about 2% per year.

Mankiw, Romer and Weil (1992), using a Solow model augmented by human capital, have also found evidence in favor of the convergence thesis[5]. Their strategy, in contrast to Barro (1991), derives the variables that control for difference in steady states from the theoretical model.

Despite the empirical evidence on convergence the standard theories of economic growth have problems explaining why differences in per capita income are so persistent and why the rates of convergence are so slow. The advocates of the endogenous growth theory[6] interpret theses problems and the low correlation between initial income per capita and growth rates for the "unconditional convergence specification" across countries, as evidence against the convergence thesis. DeLong and Summers (1991) find a high correlation between the investment-output ratio and the growth of output per capita. This high correlation is additional evidence against convergence since the standard neoclassical model predicts no correlation between growth rates and savings rates. Levine and Renelt (1992) stress that the convergence result is not robust to the period examine.

It is possible to reconcile the conflicting empirical results analyzed above. Rostow's (1963) classical text on economic development emphasizes how countries need to reach a critical mass to move from one stage of development to the next. Therefore convergence occurs **within** each stage of development but not **between** different stages of development. The different stages are always separated by the same distance. This theory offers a possible explanation as to why there is a clear convergence of output per capita across OECD

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[4] The US, the regions of Europe and the conditional estimation for the countries in the Summers-Heston database.

[5] They use the Summers-Heston database.

[6] Romer (1987) or Rebelo (1991).

countries but no signs of convergence when developed and developing countries are pooled together. If there are more than two regimes, the bias in the estimation can generate conflicting results depending on the selected sample.

Azariadis and Drazen's (1990) theory of threshold externalities in economic development can be considered as a modern interpretation of the Rostownian stages of economic growth. In their analysis, there exists several locally stable equilibria in the long run per capita output. They present evidence of the existence of threshold externalities associated with physical and human capital. Dowrich and Gemmel (1991) have also found empirical support for the existence of structural thresholds in global development. Developing countries are able to "catch-up" with developed countries only after attaining a certain level of development. In their view, the existence of a threshold level of infrastructure prevents less developed countries benefiting from technological spillovers.

Durlauf and Johnson (1992) have reexamined the Summers-Heston data set to allow for the possibility of multiple equilibrium in the data. They have found that segregating countries into groups by initial conditions[7] improves overall fit. Their results suggest that the data is compatible with a multiple equilibrium model.

2.2. An overview of the public capital debate.

The productivity growth of the US economy declined dramatically in the beginning of the 1970's. Many alternative explanations for the slowdown in productivity have been suggested. Recently Auschauer (1989) has identified public capital as a key factor accounting for the decline in labor and multifactor productivity. Following this initial result, several studies have considered the effect of public capital on economic performance and regional development. The strategy in this literature has been to use an aggregate production function, usually a Cobb-Douglas, to estimate the relationship between output and public capital. Nevertheless, there exists some controversy about the effects of public capital given the various conflicting results. Our paper adopts a new approach for the evaluation of the macroeconomic effects of public capital on economic performance. Therefore it is necessary

[7] Initial income and/or initial literacy rates.

to outline the main contenders in the public capital debate and their ideas. The studies are classified depending on the level of aggregation of the data.

a) US aggregate data

Auschauer (1989) shows a strong correlation between US total factor productivity and US public capital. He finds that a increase of 1% in public capital implies an increase of 0.39% in multifactor productivity. In addition, Auschauer points out that most of this strong effect relies on the effect of core public capital[8] and nonmilitary infrastructure.

Munnell (1990) reaches a very similar conclusion using two additional years and revised data on public and private capital. The elasticity of labor productivity with respect to public capital ranges from 0.31 to 0.39 depending on the assumptions about returns to scale. Munnell concludes that "the drop in labor productivity has not been due to a decline in growth of some mythical concept of multifactor productivity or technical progress ... it has been due to a decline in the growth of public infrastructure".

Nadiri and Manumeas (1991) examine the effects of public infrastructure and R&D capital on the cost structure of twelve two-digits US manufacturing industries. The results highlight a significant effect of public infrastructure on production.

b) State level studies

Munnell (1990b) estimates the output elasticity of public infrastructure to be 0.15, less than half the corresponding elasticity at the aggregate level. Costa et al. (1987) report very similar results. Milá and McGuire (1987) show a small effect of public capital on production although, in their case, the explanatory variable used is 'highway capacity' and not 'total public capital'[9]. Finally, Morrison and Schwartz (1991) find, in a sophisticated econometric study, that public infrastructure has a significant impact on productive performance of firms

[8] The core public capital includes street, highways, airports, electrical and gas facilities, mass transit, water systems and sewers.

[9] Auschauer (1990) notices that highway capacity is a significant variable in the explanation of state income growth. One interesting point to highlight about this study is the use of initial income per capita as an additional regressor.

although the effect seems to be declining over time. They use a generalized Leontieff cost function incorporating non-constant returns to scale and quasi-fixed inputs.

c) Metropolitan area studies

Deno (1988) uses metropolitan areas data and a translog production function to show how the output elasticity with respect to highway capacity depends on the growth of the area in question. For declining areas, Deno estimates the elasticity to be as high as 0.57 while for areas of high growth it is 0.06. Eberts (1990) reports a very low but significant elasticity of private output with respect to public capital.

In contrast with the above evidence, several studies do not find support for a strong correlation between productivity and public infrastructure. Hulten and Schwab (1984, 1991a) show that there is no link between infrastructure and economic performance. They argue that regional productivity growth is not explained by regional differences in infrastructure. Holtz-Eakin (1992a) and Evans and Karras (1992) also conclude that the evidence available from state-level data and regional data indicates no confirmation of a positive and significant effect of state and local government capital in private output or productivity. Both studies are based on panel data techniques.

None of the above studies links the role of public capital to the convergence hypothesis. This is the central issue we attempt to address in this paper. More precisely, we want to see if there is evidence of different convergence clubs among US states and, if this is the case, it will be necessary to separate them using some criterion. The initial level of public capital is a plausible criterion. For this purpose, we need to develop a growth model and which can detect whether convergence involves one or several clubs. We address this issue in the rest of the paper.

3. GROWTH OF THE STATES AND CONVERGENCE IN A SOLOW MODEL.

3.1. The model.

The conventional method for testing the convergence hypothesis involves using the coefficient of the initial income per capita as the indicator of the speed at which convergence is achieved. The usual interpretation of

$$\ln(Y/L)_{i,T}-\ln(Y/L)_{i,0}=\alpha+\beta\ln(Y/L)_{i,0}+\epsilon_i$$

is that a negative and significant ß implies a clear sign of convergence.

However, if the alternative hypothesis is a multiple equilibrium model, a negative coefficient in the simple unconditional regression will not always imply convergence to the same steady state. Thus we want our specification to nest both hypothesis: i.e. the null hypothesis of convergence to a unique equilibrium versus the alternative of multiple regimes. Moreover, we want a theory that allows for variables which control for differences in the steady state in order to avoid introducing "ad-hoc" variables that could yield spurious convergence results.

To specify a model that allows for multiple equilibrium we use a production function that captures the effect of a possible threshold effect due to differences in variables are potentially able to generate an externality. These variables are the level of total capital, public capital and private capital per capita. Azariadis and Drazen (1990) argue these variables may represent a physical capital accumulation threshold which identify shifts in aggregate technology. Our control variables play, in this model, the role of the identifying factor.

Taking these considerations into account, the production function can be written as

$$Y_{i,t} \begin{array}{ll} =\gamma_1 K_{i,t}^{\alpha_1} H_{i,t}^{\beta_1} (A_t L_{i,t})^{1-\alpha_1-\beta_1} & CV_{i,0}<\bar{CV} \\ =\gamma_2 K_{i,t}^{\alpha_2} H_{i,t}^{\beta_2} (A_t L_{i,t})^{1-\alpha_2-\beta_2} & CV_{i,0}>\bar{CV} \end{array}$$

where Y : per capita output of state i in period t.

CV : control variable.

K : total capital of the state i.

H : human capital of state i.

A : Harrod neutral technological change.

In specifying the econometric model[10] we adopt the approach developed by Mankiw, Romer and Weil (1992) in which the variables in the conditional convergence regression are derived directly from the theoretical model. We begin with a Solow model augmented by human capital. The same representation applies to both regimes. The production function is assumed to be Cobb-Douglas with Harrod neutral technological change.

$$Y_{i,t}=\gamma K_{i,t}^{\alpha}H_{i,t}^{\beta}(A_t L_{i,t})^{1-\alpha-\beta}$$

The laws of motion of labor and technology are

$$L_{i,t}=L_{i,0}e^{n_i t}$$

$$A_t=A_0 e^{gt}$$

Given the assumptions that the saving rate is constant and the depreciation rate is the same, for both physical and human capital we have the following equations of motion

$$\dot{K}_{i,t}=s_i^k Y_{i,t}-\delta K_{i,t}$$

$$\dot{H}_{i,t}=s_i^h Y_{i,t}-\delta H_{i,t}$$

[10] Note that a large proportion of public capital, for instance highways, has a clear networking externality. This effect is very strong until a certain number of miles are constructed. After that point, when many of the cities and towns are already connected, this effect is less important. The estimation of the model that includes the effect of this variable representing the threshold externality is presented in Section 4.

Reexpressing the above equations per efficiency units of labor we get

$$\frac{\partial \hat{k}_{i,t}}{\partial t}=s_i^k \hat{y}_{i,t}-(\delta+n_i+g)\hat{k}_{i,t}$$

$$\frac{\partial \hat{h}_{i,t}}{\partial t}=s_i^h \hat{y}_{i,t}-(\delta+n_i+g)\hat{h}_{i,t}$$

Assuming steady state and substituting the expression for output we can derive the human and physical capital stock in equilibrium.

$$\hat{k}_{i,t}^*=\left[\frac{\gamma s_k^{1-\beta} s_h^{\beta}}{\delta+n_i+g}\right]^{\frac{1}{1-\alpha-\beta}}$$

$$\hat{h}_{i,t}^*=\left[\frac{\gamma s_h^{1-\alpha} s_k^{\alpha}}{\delta+n_i+g}\right]^{\frac{1}{1-\alpha-\beta}}$$

Substituting the steady state values of k and h into the production function and taking logs, we obtain the output per efficiency units in steady state. Our ultimate objective is to say something about the influence of different levels of infrastructure on convergence. For that purpose we use a linear approximation around the steady state[11].

$$\ln \hat{y}_{i,t}=(1-e^{\lambda t})\ln \hat{y}_{ss}+e^{\lambda t}\ln \hat{y}_{i,0}$$

This can be transformed into an estimable equation by subtracting the log of the initial output per efficiency units from both sides of the equation.

$$\ln \hat{y}_{i,t}-\ln \hat{y}_{i,0}=(1-e^{\lambda t})(\ln \hat{y}_{ss}-\ln \hat{y}_{i,0})$$

[11] This expression comes from the differential equation

$$\frac{dln(\hat{y})}{dt}=\lambda(\ln\hat{y}_{ss}-\ln\hat{y})$$

Next we translate the variable into observable variables by using per capita variables instead of efficiency units.

$$\ln(Y/L)_{i,T}-\ln(Y/L)_{i,0}=gT+(1-e^{-\lambda T})(\rho+\frac{\alpha}{1-\alpha-\beta}\ln s_i^k$$

$$+\frac{\delta}{1-\alpha-\beta}\ln s_i^h-\frac{\alpha+\beta}{1-\alpha-\beta}\ln(\delta+n_i+g)-\ln(Y/L)_{i,T}) \quad [1]$$

where[12]

$$\rho=\frac{1}{1-\alpha-\gamma}\ln\phi+\ln A_0+gT$$

3.2. An application to US states.

If we apply the model discussed in the previous section to the case of open economies with a high degree of factor mobility, for example the US states, we obtain the contrafactual implication that the rates of convergence should be infinite. However, the existence of adjustment costs and irreversibility conditions, which are particularly important in the case of public infrastructure, eliminate this strong implication of an infinite rate of convergence. In addition, Barro, Mankiw and Sala-i-Martin (1992) have recently argued that imperfect capital mobility and reasonable values for the parameters of a neoclassical growth model lead to a convergence coefficient that, although higher than in the case of a closed economy, is close to the value that has been found in previous empirical researches. These facts lead us to think that the model presented is a good empirical approximation for studying the convergence hypothesis.

The data used for this application is the US states. It is reasonable to expect the data for US states is more accurate than the other usual source for convergence studies, the

[12] Notice that in the equation estimated by Mankiw, Romer and Weil (1992) neither the term gT nor ρ appeared (p.20).

Summers-Heston data set. The measurement error included in the data on developing countries can significantly affect the regression results.

Appendix I explains the sources of our data as well as the construction of the data series on savings rates.

We begin by considering the simplest specification where we estimate the basic convergence equation allowing for no shifts in the production function. This will serve as a benchmark model for alternative specifications in subsequent sections.

The purpose of this exercise is to serve as a benchmark case for the specification in the following sections[13].

The definition of the variables used in the estimation is as follows:

GRW: endogenous variable which measures the growth of per capita gross state product from 1969 to 1986. We use GSP instead of state income since the capital data series are used to calculate the savings rates are constructed according to the state in which the capital is located and not by owner's state affiliation. The data series for state capital only became available in 1969. The latest data on gross state product reported by the Bureau of Economic Analysis corresponds to 1986. Thus our sample is constrained between period 1969-1986.

GSP69: logarithm of the per capita gross state product in 1969.

NDG: average value over the sample period of the sum of the growth rate of the labor force, technological change and depreciation over the sample period. As in Mankiw, Romer and Weil (1992) we take the growth rate of technology to be equal to 0.02 and the depreciation rate to be 0.03.

S1: average proportion of real GSP invested, taking into account public and private sector, in the period 1969-86.

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[13] Holtz-Eakin (1992) has estimated, in a research parallel to this paper, the same kind of equation for US states data but using a different source for public capital, a shorter time period and a different method of estimation.

S2: average investment as a percentage of GSP when nonfarm, nonmanufacturing capital is increased by 25%. The reason for considering this second measure of state savings is because the estimate of nonfarm, nonmanufacturing capital constructed by Munnell (1990b), when sum across states and all subsectors, is around 75% of the Bureau of Economic Analysis national total.

HS: the number of high school graduates as a proportion of the population 25 years old or older (average of 1970 and 1980 surveys).

MT4: persons with 4 or more years of college education as a proportion of population 25 years or older (average of 1970[14] and 1980 surveys).

It should be stressed that the variables associated with human capital, HS and MT4, are stocks and not flows. The use of flows (savings rates) to reflect the impact of human capital is, in this case, inappropriate since there is a large mobility of students pursuing college education across the different US states. Consequently the specification we have to estimate is not [1] but the following:

$$\ln(Y/L)_{i,T}-\ln(Y/L)_{i,0}=gT+(1-e^{-\lambda T})(\rho+\frac{\alpha}{1-\alpha}\ln s_i^k$$

$$+\frac{\beta}{1-\alpha}\ln hk_i-\frac{\alpha}{1-\alpha}\ln(\delta+n_i+g)-\ln(Y/L)_{i,T}) \quad [2]$$

Table 1 describes the results for specification [2] where we use different variables to account for the savings rates and the human capital variables[15]. The top part of Table 1 presents the result for the linear unrestricted model

[14] The average is calculated using the *Almanac of the Fifty States* (1991) for 1980 and Table E in *State and Metropolitan Area data book* (1991) for 1970.

[15] Two usual criticisms to the results in section 2 concerning the effect of public capital are nonstationarity and endogeneity of the regressors in the production function. Notice that equation [2] is not subject to these criticims. In addition, if we run equation [2] with state private and public savings as explanatory variables the result do not look reasonable, as some of the production function coefficients turn negative. This implies further evidence in favor of the nonlinear effect proposed in this paper.

TABLE 1

	[1.1]	[1.2]	[1.3]	[1.4]
C	0.71	0.71	0.71	0.70
	(0.32)	(0.26)	(0.32)	(0.26)
LGSP69	-0.229	-0.344	-0.218	-0.334
	(0.075)	(0.062)	(0.075)	(0.064)
LS1	0.081	0.094		
	(0.039)	(0.032)		
LS2			0.086	0.097
			(0.039)	(0.032)
LNDG	-0.055	-0.152	-0.063	-0.155
	(0.103)	(0.084)	(0.107)	(0.084)
LHS	0.058		0.054	
	(0.073)		(0.075)	
LMT4		0.279		0.276
		(0.056)		(0.056)
R^2	0.21	0.47	0.21	0.47
λ	0.015	0.024	0.014	0.023
	(0.004)	(0.003)	(0.004)	(0.003)
χ	0.07	0.50	0.05	0.60
p-value	(0.77)	(0.44)	(0.80)	(0.43)
Θ	-1.64	0.78	-1.75	0.81
	(0.79)	(0.27)	(0.73)	(0.27)
α	0.42	0.24	0.46	0.25
	(0.11)	(0.08)	(0.12)	(0.09)
β	0.34	0.42	0.33	0.42
	(0.06)	(0.06)	(0.06)	(0.07)
R^2	0.17	0.43	0.17	0.43

Heteroscedastic-consistent standard error in parenthesis.

$$\ln(Y/L)_{i,1986}-\ln(Y/L)_{i,1969}=gT+\gamma_0+\gamma_1\ln(Y/L)_{i,1969}+\gamma_2\ln s_i^k$$
$$+\gamma_3\ln(\delta+n_i+g)+\gamma_4\ln hk_i+\epsilon_i$$

All the variables in Table 1 have the correct sign and we cannot reject the restriction on the coefficients implied by the model for any of the different specifications. This is additional evidence to support the usefulness of the approach first adopted by Mankiw, Romer and Weil (1992). It is clear from Table 1 that the model has a higher explanatory power ($R^2 = 0.47$) if we use the proportion of college graduates as a 'proxy' for human capital instead of high school graduates.

In fact, the proportion of high school graduates over the working population is not significantly different from zero in any of the regression in which it is used as a explanatory variable[16]. The reason for this finding is simple: given the level of development of the US, there is not enough variation in this variable to represent any significant effect.

The speed of convergence derived from this model is very similar to previous findings of Barro and Sala-i-Martin (1991).

Equation [2] represents the constrained version of the model. The method of estimation is non-linear least squares being $\lambda_i=(n_i+g+\delta)(1-\alpha-\beta)$.

The estimates of the share of physical and the human capital are in accordance with the "a priori" expected values. The share of capital is possibly too high when the high school variable (0.42) is used. However, if we use college education as a proxy for human capital the share of physical capital is a plausible 0.24.

The estimation of the model in both its restricted and unrestricted form yields very similar results when two alternative measures of the savings rate are used. When we use S1 the share of physical capital is smaller (0.24) than when we use S2 (0.25). Given this insignificant effect, we can select one of the two measures of the savings rate in subsequent sections. We have chosen S1 although all the results remain essentially unchanged if we use S2.

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[16] The poor explanatory power of the high school variable in convergence equations has been already noticed by Barro and Sala-i-Martin (1991). The claim in Holz-Eakin (1992b) that his estimation is robust to the use of high school or college graduates is surprising.

4.- THE EFFECT OF PUBLIC CAPITAL ON THE CONVERGENCE REGRESSIONS.

In this section, we investigate whether the initial level of public infrastructure in each state affects the results of the convergence regressions. In section 3, we presented a model that allows for separate regimes by controlling a variable which represented an externality effect. For this purpose we break the sample into subsamples according to different criteria: total capital, public capital and private capital per capita in the initial year. This approach discriminates between a situation in which the states converge within a group (local convergence) and those where all states converge to a common level (global convergence).

An example of this dichotomy is known in the development literature as a low level trap. In this situation, some countries or regions are supposed to be "trapped" in a low level of income per capita if they do not have the sufficient level of capital per capita in order to reach a high level of development. Figure 1 depicts a situation in which the savings rate depends on capital per capita in a non monmonotonic fashion. A large increase in capital per capita is needed to go from k_0 to k_1 since the intermediate equilibrium is not stable. It is the unstable equilibrium which generates the threshold. In our case, a large increase in public infrastructure is required to go beyond the threshold.

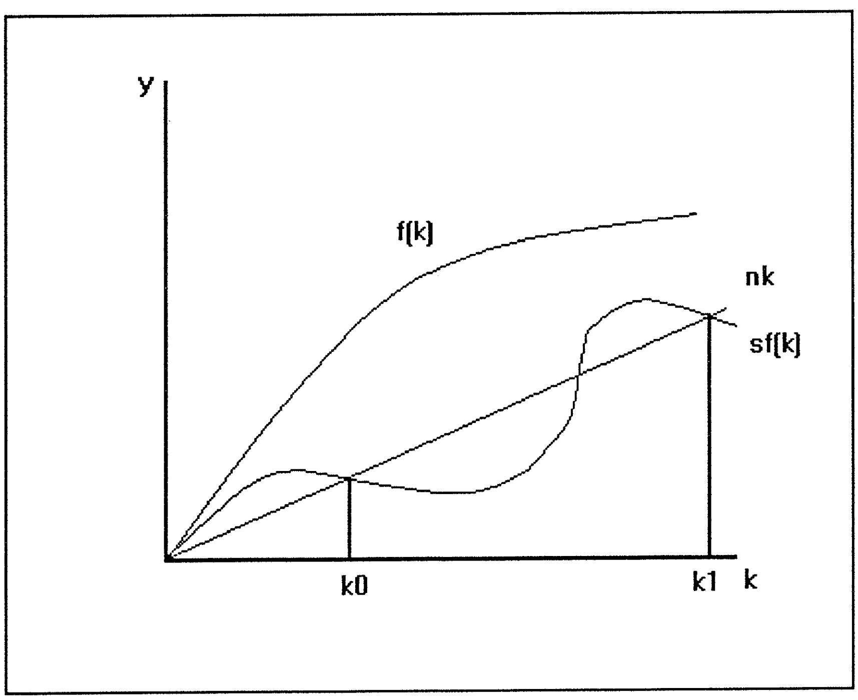

Figure 1.

4.1. Is there global convergence among the states of US?

In this subsection, we test if there is evidence of more than one convergence club across the US states. If this is the case we should estimate using subsamples of states according to some criterion. The tests performed in this section use as a maintained hypothesis the existence of a unique breaking point[17]. The reason for choosing a single threshold point is, essentially, that we only have 48 data points. To assume more than two regimes will imply working with very few observations in each regime. Therefore tree techniques, as the ones applied by Durlauf and Johnson (1992), are not considered.

The question of how to test for the existence of this break point is difficult since any statistic based on a optimal procedure to estimate the regimes will have a pretesting bias. For instance, if the chosen procedure to break the sample is to maximize the joint likelihood function of both subsamples, the Chow test will tend to make the numerator large and the denominator small creating a bias that imply overrejection of the null hypothesis (single regime). Given these problems the break point was chosen exogenously in order to test for the existence of two separate groups. Table 2 presents the tests of the null of a single regime against the alternative hypothesis of two regimes in function of total capital (TOKPC), public capital (PUKPV) and private capital (PVKPC). The Wald statistic is an asymptotic test, based in this case, in an even separation of the sample. The formula used for the calculation is

$$\chi=(\hat{\beta}_1-\hat{\beta}_2)'(V_1+V_2)^{-1}(\hat{\beta}_1-\hat{\beta}_2)$$

where the ß's are the estimated coefficients in the first and second subsamples and the V's are the estimators of the variance-covariance matrices of the coefficients.

Although for the complete sample there are no problems of heteroscedasticy, the introduction of an ordering in function of the three variables associated with the externality effect could, a priori, create problems of heteroscedasticity that would imply using the heteroscedastic-consistent estimator of the variance-covariance matrices V_1 and V_2. Table 3 presents the test of Goldfeld and Quandt for the ordered samples. In all the cases the null of homoscedasticity cannot be rejected. Based on this evidence the variance-covariance matrices used to calculate the Wald test have not been corrected.

[17] As far we know there are no procedures to choose jointly and optimally the number of breaking points and where they should be located.

TABLE 2: TEST OF CROSS SECTION STRUCTURAL CHANGE

	TOKPC	PUKPC	PVKPC
Wald	30.68 (0.000)	12.45 (0.029)	22.68 (0.000)
Wald (constrained)	20.26 (0.000)	85.93 (0.000)	11.60 (0.008)
Chow	3.67 (0.014)	6.64 (0.000)	6.20 (0.001)

TABLE 3: HETEROSCEDASTICITY TEST

	TOKPC	PUKPC	PVKPC
GQ (F-test)	0.84 (0.60)	0.99 (0.50)	0.87 (0.58)

The Wald tests in Table 2 reject the null of a single regime in the unconstrained and the constrained cases and for all three ordered samples[18]. However, there are two main concerns regarding the Wald test. Firstly, the size of our sample does not really justify the use of asymptotic tests and the bound tests for small sample have a power function that remains to be studied. Secondly, and perhaps more importantly, when the sample is broken into two equally sized subsamples, the probability of contamination of one regime with observations from the other regime is very high. To avoid these difficulties, the third row in Table 2 shows a Chow test that leaves the middle third of the sample out of the test regions. The conclusion persists unchanged: there is clear evidence of the existence of two convergence groups.

[18] This Wald test is also used in Durlauf and Johnson (1992).

4.2. Optimal break points.

The objective here is to deal with the issue of the endogenous choice of the breaking point. There has been a renewed interest for this kind of questions in the context of time series econometrics and, more specially, in the integration-cointegration literature. The discussion is centered around Perron (1989) and the consequences of endogenously selecting a break in a time trend in order to test for unit roots in the U.S. GNP. Perron (1989) finds that, in a unit root test when the alternative hypothesis is a segmented trend, you can reject the null hypothesis of the existence of a unit root the autoregressive term. However the choice of the break point for the trend was made exogenously. The oil shock was selected as the date for the segmentation of the trend. A very recent series of papers published in the Journal of Business and Economic and Statistics (July 1992) analyze the consequences of choosing endogenously the break point for a trend when the null hypothesis is the unit root hypothesis. The general conclusion is that the unit root hypothesis cannot be rejected even when the alternative is a segmented trend.

In this section, we use some of the techniques from the above literature but here in the cross section domain. In order to separate endogenously and optimally two samples, we employ a method suggested by Andrew (1989) and Christiano (1992). The procedure is recursive and involves finding the F-test with the highest value and breaking the sample at that point. In our case the maximum F-test is robust in the sense that it delivers the same regimes separation as the one based in Quandt (1958). This second approach optimize over the function

$$\max_x L(x) = -\sum_{i=1}^{2} N_{i(x)} \ln \hat{\sigma}^2_{i(x)}$$

where σ represents the standard deviation of the regression. Thus the break point should be such that the sum of the logs of the standard deviation of the regression over the two subsamples reaches a maximum.

This strategy has been recently employed in a cross section framework (Durlauf and Johnson [1992]) and in time series analysis (Bai, Lumsdaine and Stock [1992]). In the former case, the idea is to separate the countries in the Summer-Heston database using initial income per capita and level of education in order to analyze whether they converge to the same steady state. In the case of Bai et al. (1992) the idea is to date endogenously the change points in drifts in a multivariate model formed by macroeconomic variables. In our case, we try to determine whether initial total capital, private capital or public capital per capita make a difference in terms of a possible multiple equilibrium situation due to the effect of the intensity of capital on the production function.

The results are presented in tables 4 and 5. The column titles refer to the variable chosen to determine the break point. PU (public capital), PV (private capital) and TO (total capital) are the variable selected to break the sample. Looking at the unconstrained results, we see that, except for the coefficient of NDG in the first equation, all the coefficients have the correct sign. The speed of convergence is much faster in the case of the low public capital per capita states, being considerably faster than that found by other researchers. The same result can be found in the case in which total capital is use to separate the samples[19]. It is interesting to notice that when private capital is used to separate the samples, the rates of convergence and the value of the coefficients for the savings rates and LNDG are very similar[20]. The interpretation of this result is that private capital plays a role only as a regular factor of production and does not shift the production function. Public capital plays a different role, as reflected in the estimation of the regimes based on total and public capital. It affects largely the speed of convergence and the shares of labor and capital, both physical and human. In addition, the importance of the separating subsamples by using public capital per capita should be emphasize since it leads to the lowest sum of squared residuals than using any of the other two separating variables.

With respect to the constrained regressions the size of the shares of physical and human capital are reasonable. High capital per capita states have larger physical capital share than the other states.

The economic policy implications of this exercise are clear: any reduction in the rate of investment in public infrastructure by a particular state will lead to a lower standard of living in this state that will not be reversed by the simple process of decreasing marginal productivity of capital. If all the states apply the same kind of policy we will see convergence among the states but, if the main proposition of this paper holds for countries[21], we will see

[19] The same pattern is found in Durlauf and Johnson (1992) when the break is based in initial income per capita.

[20] In fact the one regime null hypothesis would not be rejected if the constant and the parameter on the human capital stock were closer in both samples.

[21] Difficult to verify empirically because only 4 or 5 countries have public capital figures.

TABLE 4

	[PU.1]	[PU.2]	[PV.1]	[PV.2]
C	0.78 (1.46)	0.14 (0.32)	0.08 (0.38)	0.61 (0.37)
LGSP69	-0.48 (0.19)	-0.28 (0.07)	-0.34 (0.14)	-0.33 (0.07)
LS1	0.002 (0.080)	0.12 (0.04)	0.15 (0.07)	0.12 (0.04)
LNDG	0.002 (0.230)	-0.19 (0.09)	-0.22 (0.18)	-0.12 (0.11)
LMT4	0.48 (0.10)	0.22 (0.07)	0.32 (0.09)	0.17 (0.07)
R^2	0.74	0.46	0.54	0.53
λ	0.038 (0.007)	0.019 (0.003)	0.024 (0.006)	0.023 (0.003)
θ	0.77 (0.67)	0.72 (0.30)	0.95 (0.46)	0.96 (0.29)
α	0.18 (0.30)	0.31 (0.08)	0.27 (0.20)	0.34 (0.08)
β	0.64 (0.30)	0.39 (0.06)	0.40 (0.11)	0.31 (0.06)
R^2	0.59	0.45	0.48	0.54

TABLE 5

	[TO.1]	[TO.2]
C	0.30 (0.36)	-0.02 (0.52)
LGSP69	-0.46 (0.10)	-0.22 (0.10)
LS1	0.09 (0.06)	0.12 (0.04)
LNDG	-0.09 (0.16)	-0.18 (0.12)
LMT4	0.41 (0.07)	0.25 (0.08)
R^2	0.70	0.37
λ	0.036 (0.004)	0.014 (0.004)
Θ	0.96 (0.33)	0.51 (0.44)
α	0.14 (0.17)	0.36 (0.11)
β	0.42 (0.10)	0.40 (0.09)
R^2	0.59	0.36

a stagnant US economy that will not be able to achieve the standard of living of other developed countries.

5.- CONCLUSIONS.

This paper has shown how the approach adopted by Mankiw-Romer-Weil (1992) is very useful not only in explaining convergence among countries but also to analyze convergence among the US states. The convergence rate obtained for the case of a single regime is very similar to those find by other researchers. However, we have found evidence of heterogeneity among the different states. Recognizing the fact that public infrastructure can produce an externality that shifts the production function, we have separated endogenously two subsamples by using some control variables. We find that the rates of convergence of states with high and low levels of per capita public capita are very different. Reductions in the rates of public investment could lead some states having a lower standard of living permanently.

APPENDIX I

SOURCES OF THE DATA AND CONSTRUCTION OF THE STATE SAVINGS RATE

The data on gross state product and state population are taken from the Statistical Abstract of the US[22]. The data on state education attainment come from the State and Metropolitan Area Data Book. The state savings rate were constructed using the state public and private data constructed by A. Munnell and generously provided by her assistant L. Cook. The data is composed of six series of capital for each of the states from 1969 to 1988. Total public capital is formed by adding up highway capital, water and sewer systems and other public capital. The total private capital is constructed by summing capital associated with farming, manufacturing capital and non-farm non-manufacturing capital[23]. The methodology followed to construct the different series is based in the procedure used to calculate the national totals by the Bureau of Economic Analysis (1987). The first step is to deflate annual data on nominal dollar investment into constant dollar inflation using a deflator. Then the value of the discarded capital is calculated using as a retirement pattern the modified Winfrey S-3. The discards represent the capital goods are retired before the end of their service life and some other remain in service longer. Using the perpetual inventory method the BEA gets the gross value of the capital stock. The state capital estimates are controlled by the total public capital and total capital published by the BEA by adding up the different kinds of capital over all the states. The problem is that for the construction of the private capital series there is only available, on a state basis, the manufacturing investment. Therefore the perpetual inventory method could not be used in this case. Instead the national totals for the different kinds of capital where apportionated in function all the available sectoral censuses[24].

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[22] The data was kindly provided in a magnetic support by Xavier Sala-i-Martin.

[23] To understand the way in which this series are assembled the reader can refer to the appendix A in Munnell (1991b).

[24] See Munnell (1991b) appendix A.

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